studies. Natural remnant directions from 21 units at five sites (24 to 29° north lat.) suggest an average northward translation of roughly 10° since late Miocene time, and a probable 45° clockwise rotation (post 6 m.y.B.P.) of the San Ignacio flows.

The Paleomagnetically indicated rate of absolute motion of the peninsula is 11 cm per year since 5 m.y.B.P. and 3.5 cm per year prior to 5 m.y.B.P., assuming an offset axial dipole. Absolute northward motion, assuming a geocentric axial dipole, is 18 cm per year from 0 to 5 m.y.B.P., and 3.5 cm per year from 5 to 19 m.y.B.P. The rates of northward motion described by Atwater and Molnar, and Dickinson for the same time spans are 3.5 cm per year and 1.5 cm per year, respectively.

Possible solutions to this discrepancy are: (1) Baja California is part of a broad shear zone of the plate margin, and has had more movement along faults within the proto-gulf and the present margin of western Mexico than previously deduced, (2) the North American plate has no northward motion, or (3) the North American plate has had northward motion since the Miocene, with the amount of motion of the plate margin being equal to that described by T. Atwater and P. Molnar; thus, the paleomagnetic data show both motions.

Studies by M. J. Kamerling and B. P. Luyendyk, and continued paleomagnetic studies at San Diego State University, show a comparable amount of northward motion for southern California and northwestern Mexico during the Miocene. Paleomagnetic results would imply that the present palinspastic reconstructions have not completely resolved the tectonic framework of the Pacific–North American plate boundary.

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Resolution of Reefs, Overthrusts, and Pre-Volcanic Sediments by Electrical Geophysics

Today's explorationist is generally unfamiliar with the potential and success of surface-based electrical resistivity methods as geophysical tools useful in reducing exploration and reserve-areas definition costs, as well as drilling costs. Two major reasons for this are: (1) the promise of direct detection of hydrocarbons where surface-based electrical methods have been used to delineate shallow subsurface anomalies; and (2) the geophysical data from electrical methods are more complex than simple anomaly profiles and require a specifically educated and costly consultant to do the interpretation.

In spite of the above, the electrical methods may be used directly as a resistivity-defining tool which not only delineates structure but also provides information necessary to resolve lithologic and stratigraphic problems, such as rock type, fluid content, and porosity. In areas where seismic data quality is poor because of adverse conditions, such as volcanics, electrical techniques are unaffected and, in many instances, the data quality is actually improved.

To help meet the challenge of today's petroleum exploration problems, a multi-methodology electrical resistivity system has been developed. This system is used to great advantage in exploring reef, overthrust, and pre-volcanic sediment prospects. Case histories in Nevada and west Texas show resolution of these problems by electrical methods.

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Aggregate-Resources Evaluation of Lund Nevada Mapsheet

As a result of preliminary research and development work performed in support of a large proposed construction project in Nevada, an aggregate-resource evaluation was completed for 12 major valley areas within the Lund 1° by 2° mapsheet. Construction would require a total of from 95 to 124 million tons of aggregate for production of concrete and base-grade materials in over 40 valley areas where current production is 1 million tons/year.

Within the Lund mapsheet a three-phase program was initiated to assess the relatively unknown aggregate potential of the area. Each phase became more detailed than the preceding one. The phases went from regional-overview to valley-specific analyses. Results of the initial regional aggregate-resources evaluation indicated that sufficient acceptable coarse aggregate could be obtained from Quaternary alluvial-fan and lacustrine basin-fill deposits and Precambrian and Paleozoic carbonate and quartzitic rock sources. Sufficient acceptable fine-aggregate sources were not readily available in the area. During the two subsequent valley-wide studies, geomorphologic division of basin-fill deposits, based on interpretation of aerial photography and ground reconnaissance in conjunction with the results of exploratory drilling and trenching, seismic refraction and laboratory testing, established the extent, composition, and quality of these units. These data refined and confirmed initial aggregate results. Additionally, limited trial concrete-mix test results indicate that high-strength concrete (6,500 psi compressive strength at age 28 days) can be made from selected basin fill and rock sources using standard mix designs and admixtures.

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Evaporite Mineral Cycles, Paradox Basin, Utah and Colorado

The evaporites of the Paradox Member of the Hermosa Formation of Pennsylvanian age in southeast Utah and southwest Colorado are direct precipitates from marine brines and have been changed only slightly by subsequent events. Geophysical logs of deep wells indicate that the Paradox Member is composed of 29 evaporite cycles. Lithologies that make up the cycles, in order of increasing salinity, are: black calcareous shale, dolomite, anhydrite, and halite (with or without potash). Studies of cores from two wells in the central part of the basin show that some of the cycles in the upper part of the Paradox Member are remarkably symmetrical above and below the black shale, indicating regular changes in salinity. Lithic texture, crystal morphology, and bromine distribution are suggestive of primary sedimentation with only minor early diagenesis related to burial dehydration.

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Physical Evidence for Saline Cycles of Deposition in Eocene Lake Gosiute in Southwest Wyoming

The Wilkins Peak Member, the saline unit of the Green River Formation in southwest Wyoming, is more than 985 ft (300 m) thick and contains more than 35 beds of trona or trona with halite. The trona and halite were deposited in the deepest part of the basin of Lake Gosiute, during arid periods of the Eocene Epoch, by the periodic evaporation and contraction of the lake waters. Alternating with the arid periods were more humid periods, when the lake expanded and less saline sediments were deposited across and beyond the previously deposited salt beds. The water-level fluctuations resulted in a concentric pattern of lithofacies within the Wilkins Peak Member.

The innermost of the cyclic lithofacies, which includes bedded evaporites, occupies the depositional center of the ancient lake basin and consists of repetitious ascending sequences of (1) dark-brown oil shale, (2) white to brown trona and halite, and (3) gray or green dolomitic mudstone. A second lithofacies that encircles the first, but does not contain bedded evaporites, shows in vertical section cyclic sequences of (1) gray siltstone, (2) dark-brown oil shale, (3) tan or light-brown oil shale, and (4) gray or green dolomitic mudstone. The oil shale and siltstone in these cycles were deposited as lake-bottom muds and along ephemeral shorelines during periods of lake expansion and water-freshening; the trona and halite and gray and green mudstone were deposited in salt pans and on mud flats during periods of lake contraction and water-salting. A third lithofacies is present at the outermost margins of the lake basin, but the cyclic sequences there, consisting mostly of gray and green mudstone and some thin interbedded tan and brown oil shale, are largely obscured by irregularly interbedded tan algal limestone, oolites, and thin beds of dolomite and sandstone. Floodplain deposits of interbedded red and gray sandstone and mudstone are present nearly everywhere between the outer edges of the lake basin and surrounding mountains.

The number of major contractions of Lake Gosiute during deposition of the Wilkins Peak Member can be determined by counting the number of oil shale beds involved in cyclic sequences near the depocenter of the basin. Seventy-three oil shale beds, and hence 73 saline cycles, were counted in a hole cored in the Blacks Fork area by the U.S. Energy Research and Development Administration. Histograms of oil shale beds in drill holes and outcrops in other parts of the basin support 70 to 75 as the probable total number of saline cycles.

The time intervals of the saline cycles can be roughly estimated by using potassium-argon dating methods for biotites in tuff, and by counting oil-shale varves. From these data, the shortest cycle in which salines were deposited is believed to have lasted less than 1,500 years and the longest cycle more than 100,000 years.

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Geology and Mineralogy of Vogel Specialty Sand Deposit, Barstow, San Bernardino County, California

The Vogel specialty sand deposit contains on the order of 16 million tons of potentially economic dune sand. The immediate source is the fluvial deposits of the Mojave River adjacent to the site on the west. These fluvial sands are derived primarily from the Mesozoic granitic bedrock units of the San Bernardino Mountains near Silver Lake and the Jurassic to Triassic metavolcanic bedrock units of the Silver and Sidewinder Mountain areas.

The sands contain principally feldspar (oligoclase, 40%; K-spar, 17%), and quartz (35%), with minor amounts of hydrobiotite (5%) and hornblende, tourmaline, etc (2%). The sand is very well sorted with most grains about 0.3 mm in diameter and angular to subangular.

The deposit has many similarities to the once extensive specialty sand deposits mined along the California coast prior to the restrictive coastal zone ordinances of the 1960s and 1970s.

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Land Seismic Source Study

During the summer of 1980, faculty and students from the Colorado School of Mines Geophysics Department conducted an extensive series of seismic measurements in eastern Colorado, with the objective of characterizing and comparing land seismic sources under a variety of controlled conditions. This work was sponsored by 29 companies and one U.S. government agency, and results are reported in full in a series of Master of Science theses completed during the fall term, 1981, at Colorado School of Mines.

The test site for the measurement program was located near Brush, Colorado, on gently rolling range land. The site was selected on the basis of easy access, geology suitable for the program objectives (thick Pierre Shale section near the surface and good reflectors at depth), nearby petroleum production and well-log information, and a landowner willing to establish a permanent test site.

The seismic sources used in this study included: (1) vertical and horizontal vibrators, (2) land airgun, (3) weight drop, (4) conventional explosives in shot holes, (5) surface explosives, (6) suspended charges in air (Poulter method), (7) Marthor (registered trademark of IFP), and (8) Betsy (registered trademark of Mapco).

The measurement program consisted of three phases: (1) three-component downhole measurements from 400 to 1,000 ft (120 to 300 m) in 100-ft (30 m) intervals for each source type over a range of horizontal offsets from 50 to 1,000 ft (15 to 300 m); (2) three-component noise spread on the surface for each source covering an offset range of 120 to 8,730 ft (37 to 2,660 m); and (3) a conventional CDP line for each source covering 3 mi (4.8 km) of subsurface with a maximum of 24-fold coverage over the center 1 mi (1.6 km).

The primary test objectives consisted of: (1) quantitative comparison of source waveforms, amplitude and phase spectra, source repeatability, source directivity, and intensity levels from downhole measurements, (2) comparison of surface-wave noise-generation characteristics between different sources from noise spread data, and (3) quantitative comparison of reflection signal characteristics (e.g., bandwidth, S/N ratio, etc) from the CDP shooting.

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Buried Pleistocene Gold-Bearing Channels, Central Great Valley, California

Ancient gold-bearing channels have long been exploited in the Sierra Nevada foothills and in the eastern Great Valley of California. Many channels have been hydraulically mined, whereas others have been dredged. Yet there remains an extensive buried channel system, particularly associated with ancient courses of the lower American and Mokelumne Rivers. The channels are identified in water-well logs, in bridge borings, and locally in quarry exposures. Near the foothills, many channels are expressed geomorphologically by fluvial-filled terraces, many of which have been dredged, and some are even now exploited for gold and aggregate.

At least five now-buried channels were cut and filled by the lower American River. These channels emerge from the foothills near Folsom and are traced in the subsurface to depths of 115 ft (35 m) below present sea level. Some channels are over 25 mi (40 km) long, and 20 to 33 ft (6 to 10 m) thick. The channels are named Older Fair Oaks (oldest), Younger Fair Oaks, Older Riverbank, Younger Riverbank, and Modesto, respectively, after the formations in which they occur.

Five buried channels underlying the lower Mokelumne River are best defined between Clements on the east and Lodi on the